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Research on Risk Assessment Technology of the Major Hazard in Harbor Engineering

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Abstract

The increased construction of harbor infrastructure has led to distinct safety problems recently. A lack of an efficient risk assessment method to evaluate the major hazard (procedure) in harbor engineering has become a vital reason for frequent grave accidents in harbor engineering area. This work, taking the features of harbor engineering into account and starting from the basic concept of “risk”, sets a risk level evaluation standard for both accident consequence measure index and accident possibility measure index based on the survey of current situation of construction enterprises, thus realizing the quantitative assessment and classification towards major hazard and providing rules for major hazard risk assessment on harbor engineering project in the future.

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Introduction

In “The specification of occupational health & safety management system” [1], “hazard” is defined as “the root or state that leads to damage, illness, property loss, working environment breaking or combination of these situations.” While in the “major hazard identification of dangerous chemicals” [2], “major hazard identification of dangerous chemicals” is defined as “long-termly or temporarily produce, process, transport, use or store up chemicals, and the number of chemicals equals to or surpasses the threshold quantity.” For a long time, the concepts of “hazard”, “major hazard” are used by supervision department of traffic construction safety at all levels, construction units, and construction enterprises. This work, taking the features of harbor engineering and the distribution of hazards into account, defines “hazard of harbor engineering” as “construction activities, dangerous material, and bad natural

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environment and so on that may lead to casualty and property loss in the process of harbor construction”. And the concept of “major hazard of harbor engineering” emphasizes the level of materiality of casualty and property loss based on the definition of “hazard”. The definitions of “hazard of harbor engineering” and “major hazard” in this work are recognized by experts and scholars in the harbor engineering field.

1. The feature of harbor engineering and the emphasis of this thesis

Harbor engineering, belonging to the category of civil engineering, has a lot in common with other kinds of engineering in this category in terms of its content and applying technology, while its service targets at the waterborne transportation industry [3]. Most of the harbor engineering projects need field operation and over-water operation. Most of the operations feature multi-process and interchanging. During the process, many constructive ships and large cranes will be operating in a narrow working place where natural disasters such as typhoon, flood, storm tides and landslides may post serious threats to the engineering project. All these situations could easily lead to major casualty and property loss such as crane accident, object strike, car and machine damage, electric shock as well as drowning.

In recent years, with the expanding scale of harbor engineering, harbor construction area has been extended to deeper and further water far away from coastline. Moreover, the number of specialized harbors has been raised, meanwhile there emerges more harbor reconstruction and expansion projects and dangerous cargo harbor construction. When all the fundamental changes happen together with an increase in construction difficulty and operational environment complexity, safety issue in the process of construction becomes particularly acute [4]. Previous accidents show that one of the important reasons for the frequent major accidents in harbor engineering area lies in lack of an efficient method to identify and evaluate risks, hence, failing to make up a special scheme for construction safety as well as a valuable measure to deal with safety problems in harbor engineering.

In the “major hazard identification of dangerous chemicals” [2] as well as the “suggestion on the development of supervision work on the major hazard” by State Administration of Quality and Technical Supervision ([2004] No.56), there are clear rules for dangerous materials. Due to limited space, this thesis only explored the risk assessment technology of the major hazard in harbor engineering.

2. The method selections to assess major hazard in harbor engineering.

The method to assess safety is the tool to do quantitative and qualitative assessment. According to the quantification of the safety assessment result, the methods to assess safety can be divided into qualitative and quantitative methods. Currently the main qualitative methods include: preliminary hazard analysis (PHA), hazard and operability study (HAZOPS), assuming failure analysis and assuming failure /checklist analysis, and failure type and impact analysis, etc. While quantitative methods include: Dow F&E index method, Mond evaluation method by British Imperial Chemical Industries, probability theory analysis method, fault tree analysis (FTA), etc. Half quantitative assessment methods include: LEC, checklist analysis method with grades, etc. All these risk assessment methods feature their own advantages and scope of application. Qualitative and quantitative as well as half quantitative assessment methods can be applied according to the system complication and assessment purpose. When selecting one of the methods to be applied, we decide based on the specific factors such as characters of the industry [5].

The objective of risk assessment technology of the major hazard (procedure) in harbor engineering is to do qualitative and quantitative assessment first and then classify them into different levels, based on which, different constructive control and management strategies will be set out. Due to the character of over-water construction, the risks of a specific procedure in harbor engineering will be different in terms of different constructive technologies, constructive enterprises as well as different constructive locations. All these make the quantitative assessment of harbor engineering a difficulty.

We make a survey on the major harbor engineering constructive enterprises, including: the First Navigational Engineering Bureau, the Third Navigational Engineering Bureau, the Fourth Navigational Engineering Bureau and their relevant construction companies, as well as Shanghai harbor engineering company, and Yangtze Chongqing fairway engineering company, etc. According to the survey, all these companies use LEC to assess the risk of major

hazard. LEC, as a method to assess the danger level in a constructive environment with potential risks, is easy to apply and owns a relevant clear classification of danger level [6]. However, it relies mainly on personal experience to decide the score of the three factors and classify the danger level, which means the assessment procedure could be affected by subjective factors and the assess process cannot be combined with constructive technology and environment. The survey result shows that the score of every factors in the assessment procedure varies from company to company, and the assessment results are also different from each other. In a word, it is imperative to set out a proper assessment method that goes with the specific situation of assessing major hazard in harbor engineering.

3. Assessment technology of major hazard in harbor engineering

In the theory of modern safety science, safety is a descriptive state in the process of system operation, a state variable that opposite with danger. As a system, Harbor engineering features fuzziness. While the hazard in the procedure, as one side of the state of system operation, also features fuzziness. Hence, it is much difficult to describe the risk of major hazard correctly and objectively unless the constructive technology and environment are taken into account.

This paper, in the light of the character of harbor engineering, sets out the assessment standard of measure index realizing the transformation from qualitative assessment to quantitative assessment. Meanwhile, combining with practical constructive situation, this paper does a quantitative calculation on the major hazard in harbor engineering so as to realize the danger level classification on major hazard (procedure).

3.1. The principle of risk assessment of major hazard in harbor engineering.

In the occupational safety and health management system of China, “risk” is defined as “the combination of the possibility and consequence of the occurrence of a certain dangerous situation”. Risk of the major hazard (procedure) in harbor engineering is the product of the possibility and the consequence of the potential accident in the process of construction. It can be formulated as below:

$$R = P \times C \quad (1)$$

- R Risk value
- P Possibility of accident
- C Consequence of the possible accident

3.2. Procedures of risk assessment of the major hazard in harbor engineering

Risk assessment of the major hazard in harbor engineering contains six procedures as shown in Fig. 1 below:

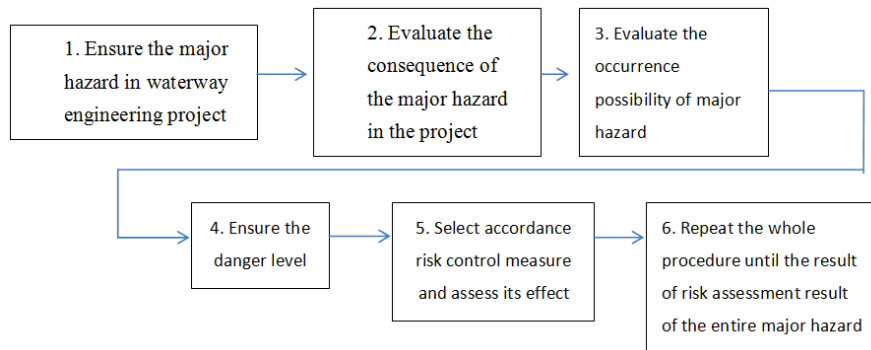


Fig. 1. Chart of harbour engineering major hazard risk assessment procedures.

3.3. The measure indicators of the consequence and possibility of the major hazard accident in harbor engineering

3.3.1. The consequence of the major hazard accident in harbor engineering

- There are mainly two indicators to measure the consequences of the major hazard accident in harbor engineering: personal injury and property losses.
- The assessment of accident consequences.

Table1 shows the criteria of indicators to measure the accident consequences.

The scores of personal injury (I) and property loss (L) will be decided according to Table 1, and then we divide the added score of I and L by two to get the consequence score (Cs), the formulation is as follows:

$$Cs = (I + L) / 2 \quad (2)$$

According to the criteria of Table 1, the major hazard (procedure) in a specific harbor engineering technology can be scored and calculated.

Table 1. Determine criteria of indicators to measure the accident consequences.

Consequence measure indicators	Determine Criteria	Score
Personal Injury (I)	3 person or more die	3
	1-3 person die	2
	no death but personal injury	1
Property Loss (L)	Causes serious damage to equipment, ship, and bank slope which cannot be repaired in short time. Causes property loss of more than 10 million ¥.	3
	Causes big damage to equipment, ship, and bank slope and causes property loss between 1-10 million ¥.	2
	Causes slight damage to equipment, ship, and causes a loss under 1 million.	1

Note: if no casualty, property loss or environmental impact occur, then the score should be 0.

3.3.2. The possibility of harbor engineering accident

a. Five indicators to measure the possibility of accident

The reliability of the accident: the reliability of an accident should be judged on the basis of comparing it with other similar accidents in an engineering project and combing it with the information provided by relevant departments. The more reliable the accident is, the greater possibility there will be.

The frequency of exposure: the frequency of exposure refers to the frequency and predictability of people's exposure (beside or below water) and machine's position (hanging) in construction process. The more frequent people and machine expose, the higher predictability it will have, and the greater accident possibility there will be.

The sensitiveness to natural environment: the sensitiveness to natural environment means the sensitive level of engineering project towards natural conditions such as wind, wave, thunder, snow, rain, fog, tide, and so on. The greater impact natural environment brings to engineering, the more possibility of accident occurrence there will be.

The maturity of technology: it means constructor's technological skill. The less skilled technology, the more accident possibility.

The density of labor: it represents the labor demand in engineering project. The more demand on the number of labors, the more possibility of accident occurrence.

b. Assessment on the possibility

According to Table 2, the scores of the five measure indicators----the reliability (R), frequency of exposure (F), sensitiveness to natural environment (A), maturity of technology (S), and density of labor (L) can be achieved. After adding the 5 scores and dividing the result by 5, the score of possibility (Pr) could be achieved, the equation is:

$$Pr = (R + F + A + S + L) / 5 \quad (3)$$

According to Table 2, the five measure indicators of the vital procedure in a specific harbor engineering process can be scored and calculated.

Table 2. Determine criteria of indicators to measure the possibility of the accident.

Possibility measure indicators	Determine Criteria	Score
reliability (R)	High level reliability. For example, the same accident has ever occurred for many times in other similar engineering projects or relevant departments have provided information which suggests the high possibility of accident occurrence.	3
	Medium level reliability. For example, the same accident has ever occurred in other similar engineering projects, or relevant departments have provided information which suggests the possibility of accident occurrence.	2
	Low level reliability. For example, the same accident has seldom occurred in other similar engineering projects or relevant departments have provided information which suggests the low possibility of accident occurrence.	1
frequency of exposure (F)	High level. For example, when in construction, people constantly exposes to waterside or underwater or exposes to waterside at a particular time; the machine is hanging in the air all the time or for most of the time.	3
	Medium level. For example, when in construction, people exposes to waterside or underwater for some times; the machine is hanging in the air for some times; or the time of people exposes to waterside or under water as well as the time of machine hanging in the air can be predicted.	2
	Low level. People exposes to waterside and machine hang in the air for a short time.	1
sensitiveness to natural environment (A)	High level. Natural conditions such as wind, rain, fog, snow and tide have seriously bad impact on engineering project.	3
	Medium level. Natural conditions such as wind, rain, fog, snow and tide have some impact on engineering project, but not obvious.	2
	Low level. Natural conditions such as wind, rain, fog, snow and tide have no impact or little impact on engineering project.	1
maturity of technology (S)	Immature level. The constructive technology has never been applied before.	3
	Medium mature level. The constructive technology has been applied but not often.	2
	Mature level. The constructive technology has been applied for many times.	1

Note: if not related to one of the indicators, then the assessment score of this indicator should be 0.

3.4. The classification of the major hazard risk level in harbor engineering project

The risk value (Ri) of a specific procedure in harbor engineering equals to the product of consequence score (Cs) times possibility score (Pr):

$$Ri = Cs \times Pr \quad (4)$$

The risk of the major hazard in harbor engineering can be classified into 3 levels:

- Low level: the third-class hazard with the risk value (R_i) <3 .
- Medium level: the second-class hazard with the $3 \leq \text{risk level } (R_i) <6$.
- High level: first-class hazard with the risk value (R_i) ≥ 6 .

Based on the above classification, the achieved risk value R_i can determine the risk level of the major hazard that is evaluated.

4. Conclusion

This paper, based on the constructive features of harbor engineering in China, proposes a complete technical method and procedure to assess the major hazard in harbor engineering. Through applying the assessment method and procedure in the phase II engineering project of the general harbor in Chaofeidian, Tangshang, as well as the constructive project of BeiGangchi 5#-7# berth in Beijiang harbor, Tianjin, and combining the opinions of constructive enterprises and project managing personnel, we make a conclusion of the characters of the method, including:

- Wide range of application and easy operation. This method can not only be applied by constructive enterprises for self-assessment of the major hazard in harbor engineering, but also be used by safety supervision department, constructive organization and intermediary agency to assess the major hazard in harbor engineering. This method is easy to operate and calculate, and is understandable and applicable for people of different educational levels.
- Adequate theoretical basis and full factors taken into account. This method is proposed on the basis of the fundamental theory of safety system engineering, the definition of “risk” as well as the characters of harbor engineering. The objectivity and comprehensiveness are ensured by putting together the assessing method and project characters and taking the different factors such as constructive technique and condition into account.
- Clear classification of assessing process and objective assessing results. This paper proposes the assessing procedure of the major hazard in harbor engineering as well as the scoring standard of the consequence and possibility of accident. Moreover, it further comes up with the risk level classification method of the major hazard in harbor engineering. The classification method features reasonable structure, clear classification and convenient application. Its application in the two projects mentioned above has proved to be objective and reliable.

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